AHMCT Roadmap for Research, January 25, 2007

Outcome — Innovative highway technologies that improve safety, increase quality, reduce congestion and costs, and integrate operations through:

- Identifying best practices,
- Developing innovative work methods,
- Standardizing specifications,
- Performing evaluations and tests,
- Developing innovative devices and machines,
- Applying information technology.

OVERVIEW: Research Areas and Problem Statements

Research Areas	Employee Safety	Winter Maintenance	Roadside	Homeland Security	Planning and Operational Efficiency
Funding Last Five Years	$3.34 Million	$1.56 Million	$1.10 Million	$180,000	$3.46 Million
Problem Statements	Develop methods and equipment that would assess and improve safety of highway construction and maintenance operations and provide protection for highway workers.	Develop methods, equipment, and software that would assess and improve safety, reliability, and efficiency of highway winter maintenance operations.	Develop methods, equipment, and software that would assist in planning, construction, and maintenance of roadsides.	Develop methods, equipment, and software that would integrate Homeland Security into highway construction, maintenance and operations.	Develop methods, systems, and software that can improve the efficiency and reliability of transportation planning and operations.
Overview — AHMCT Objectives	Mechanization of Highway Construction and Maintenance Tasks allowing removal or reduction in the number of workers on the roadway and placing them on the roadside or inside maintenance vehicles. Development of risk assessments as well as new designs and concepts for positive worker protection systems and barriers.	Develop the ability to plan and perform winter maintenance using state-of-the-art technology to allow for the fastest, safest, most environmentally-friendly, and most cost-effective methods. This includes the investigation of existing methods as well as the development of new methods, software, devices and machines.	Develop the ability to plan, construct, operate and maintain roadsides through the use of state-of-the-art technology to allow for the fastest, safest, most environmentally-friendly, and most cost-effective methods. This includes the investigation of existing methods as well as the development of new methods, devices and machines.	Develop the ability to improve Homeland Security by integrating it into highway infrastructure and applying advanced automation, IT, robotics, and systems engineering technologies	Address current transportation system planning and operational needs using advanced automation, IT, systems engineering, and best business practices.
Recent Research — Ongoing Projects	**Barriers** — Mobile Safety Barriers, Temporary Barriers in Work Zones **Crack Sealing** — Longitudinal Crack Sealer, Random Crack Sealer **Debris** —Debris Vacuum Vehicle, Debris Removal Vehicle **Manual Tasks** — Labor Intensive Manual Tasks **Markers and Stripes** — Raised Pavement Markers **Traffic Cones** — Cone Placement Vehicle **Balsi Beam Risk Assessment** — Perform a risk assessment and injury cost reduction for the Balsi Beam based on fatal data.	**Snowplow Guidance** — Magnet-based guidance for snowplow and rotary plow vehicles. **GPS-Based Guidance for Winter Maintenance** — GPS-based Guidance for Roadway Pass Opening, snowplows and rotary plows **Obstacle Detection in Snow and Ice** — Assessment of current methods and design of novel methods for guardrail protection **Information System** — In-vehicle Information System for Snow Crew Supervisors	**Vegetation** — Herbicide Control and Spray Vehicle, Vegetation Removal Tools **Roadside Inventory** — Identify best practices and available technologies for monitoring conditions of roadside features. Make recommended practices	**Rapid Road Repair**	**Vehicle Allocation Methodology** — Identify best practices and make recommendations for vehicle allocations for general services **PDA-Type Travel Behavior Data Monitor** — Development of a digital electronics-based data monitor with GPS integration for travel diary **Bridge Profile Measurement System** — A Laser-Based System for vertical and horizontal Bridge Profile Measurement **Benchmarking Standards for 3D Laser Scanning Systems** — Test and develop benchmarking standards for evaluation and selection for Caltrans applications **Open-Source ATMS** — Investigate use of open-source software and architecture for ATMS **Deployment Support** — Cone Machine; Travel Behavior Data Monitor; Longitudinal Sealing System
Future Research — What else is needed	**Barriers** — Temporary Barriers in Work Zones: Detailed Implementa-tion, Mobile Safety Barriers: Design and Test **Crack Sealing —** Automated Longitudinal and Manual Full Lane Sealing, Automated Full Lane Sealing. **Debris** — Enhanced Deployment Support, Development of Low Cost Removal Equipment. **Manual Tasks** — Labor Intensive Manual Tasks **Markers and Stripes** — Raised Pavement Marker (RPM) Placement — Development of Field Prototype and a ruggedized system **Traffic Cones** — Traffic Cones and Lane Closures: Diffusion of Innovation **Balsi Beam** — Crash Test and Simulation; Risk Analysis Based on (non-fatal) Injury Data; Modified Design; Deployment Decision Tool	**GPS-Based Guidance for Winter Maintenance** — Field Operational Testing; Revised Systems based on Operator Feedback; Ruggedized System Design and Deployment **Plug-In Display-Based System for Driver Assistance for Maintenance Vehicles** — Evolve the GPS-Based Guidance System into a generic and portable in-cab display-based system for driver guidance for maintenance vehicles. **Obstacle Detection in Snow and Ice** — Field Testing of a Side-Fire Radar System for Guardrail Detection and Ranging; Ruggedization and Deployment **Information System** — Field Testing and Integration with further data sources such as WeatherShare	**Vegetation** — Vegetation Removal Tools, Herbicide Vehicle **Roadside Inventory** — Develop a visualization interface and a database for roadside asset management; Develop field user guide based on the recommended practices for each roadside asset; perform monitoring operation and populate the database/visualization asset management system.	**Rapid Road Repair** — Continued development of tools and procedures that Caltrans needs to maintain a right-of-way during emergency situations.	**Vehicle Allocation Methodology** — Perform Pilot Project Implementation for the Division of Maintenance **PDA Type Travel Behavior Data Monitor** — Hardware revision for mass production; Tools for data analysis and automation **3D Laser Scanning Systems — Sensing and Modeling** — Field Trials and Demonstration in specific Caltrans applications; Develop a Vanguard Type System for 3D Laser Scanning **Open Source for Maintenance & Operations** — Initiate and Maintain an Open-Source Web-Based Community for Highway Maintenance and Operations **Deployment Support** — Cone Machine, Bridge Profile Measurement System, Crack Sealing Systems; ARDVAC; DRV; RPM; Balsi Beam; Roadside Inventory Data Collection
Outcomes	*See Project Details following for detailed information.*				

DETAIL: Research Roadmaps

Employee Safety

Research Area	*Recent and Ongoing Research*	*Future Research*	*Research Products and Outcomes*
Barriers What are the best practices for cordoning off work zones with barriers? Can new devices and/or innovative work methods be employed to improve employee safety in work zones? How can Balsi Beam Deployment be enhanced?	**Temporary Barriers in Work Zones** The project entailed study of temporary barrier applications in work zones and available technology and products. The project will lead to a web-based toolbox that will allow work zone designers to quickly assess their options in terms of available products to best meet their specific needs and to assess the costs associated with the products. **Mobile Safety Barriers** This work is aimed at investigating alternative approaches towards controlling errant vehicles in and around highway work zones in order to minimize the extent of damage and injuries. The project will lead to specifications for a new mobile barrier system and a plan for further development and ultimate deployment. **Balsi Beam Risk Assessment** This work involved a risk assessment of Balsi Beam determining the cost benefit of using the Balsi Beam system in work zones. It has developed data for use justification and decision support for deployment of Balsi Beam.	**Temporary Barriers in Work Zones — Detailed Implementation** Development of the toolbox will continue toward the goal of adoption by Caltrans. The toolbox will be the current repository of new and innovative barrier devices as they are developed, tested and approved for use by Caltrans. The toolbox will contain detailed barriers information related to the installation, applications, specifications and recommendations for each product. **Mobile Safety Barriers — Design and Test** The next phase of work will entail detailed design, development and initial field operational testing of the barrier system concept resulting from the current project. **Balsi Beam Detailed Injury Reduction Study** The present study was based on fatal data due to lack of availability of other injury data. Injury data exists and should be made available to update the study to determine the benefits of the Balsi Beam in reducing all injuries. **Balsi Beam Crash Testing and Simulation** Proper rating of the Balsi Beam against standard crash tests is needed so that its performance can be evaluated against other systems. **Modified Balsi Beam Design** Modified Balsi Beam Designs can enhance its use and reduce its unit cost for different applications.	**Research Products** *Temporary Barriers in Work Zones* — Detailed Implementation: An enhanced temporary barrier toolbox. *Mobile Safety Barriers* — Development of additional mobile barrier designs and enhancements of existing designs. **Outcomes** *Temporary Barriers in Work Zones* — The temporary barrier toolbox will allow for the expedited design of work zones with information, including costs, on the latest devices readily available. This will result in better and more cost effective barrier usage and improved safety in work zones. *Mobile Safety Barriers* — The development and use of a new barrier system will improve employee safety in work zones. By providing for the best barriers to protect workers, it is anticipated that 1 death and 2 significant injuries can be prevented each year resulting in savings on the order of $1 million per year. *Balsi Beam* — Cost benefit justification for utilization of the Balsi Beam; Balsi Beam Rating against Crash Test Standards for Barriers; Decision Support for Prioritized use of Balsi Beam; Modified Balsi Beam System for enhanced utilization
Crack Sealing How can innovative technologies and automation be utilized to enhance the safety and efficiency of highway pavement crack sealing operations?	**Transfer Tank Longitudinal Sealer (TTLS)** A truck based longitudinal sealer and trailer based sealant transfer nurse kettle. Developed for high production hot applied sealing at continuous speed with no direct worker exposure to traffic and the functionality to facilitate a highway moving lane closure sealing operation. **Sealzall** *Description* — Automated longitudinal and manual sealing of all cracks – All the benefits of the TTLS system with the addition of a heated sealant application hose to support manual sealing operations and provide crack cleaning capabilities. This machine can be quickly reconfigured for either mode of operation and therefore can be utilized to seal all pavement cracks on the highway. *Status* — The Sealzall system successfully completed limited field testing with Caltrans District 4 Maintenance crews. Business analysis has shown the Sealzall TTLS can save Caltrans up to $2 million annually. The TTLS application truck is currently being rebuilt under the Sealzall development project. The sealant melting kettle has been upgraded to further increase seal production capabilities. The additional Sealzall system upgrades will be incorporated over the next year with the completed Sealzall machine returning to Caltrans for field testing and ultimately full Caltrans deployment. *Current Caltrans Deployment*: Stage 2. **Operator Controlled Crack Sealer (OCCSM)** *Description* — A truck based sealing machine with fully automated telescopic robot sealing arm. The operator stops the truck with pavement cracks in the robot work zone and supervises crack selection. The sophisticated controller operates sealing robot to inject/fill identified cracks with hot-applied sealant autonomously. *Status* — Currently this machine is operational and is progressing through the initial highway testing phase. This project was developed as a demonstration platform to showcase the technology of sealing all in-lane cracks with a highly advanced level of automation. The system will be demonstrated on the highway within the state of California in 2007. *Current Caltrans Deployment*: Stage 3.	**Automated Longitudinal and Manual Full Lane Sealing** The current Sealzall project will result in the development of a field deployable high production longitudinal and manual in-lane crack sealing system. Crack preparation with compressed air will also be incorporated and made available to both sealing configurations. Caltrans Maintenance crews will need to operate this equipment in the field and provide evaluations which will establish if additional development will be required, or if procurement of additional units will be the next phase. Another major goal in the process of developing the Sealzall project is to incorporate methods that will help simplify the procuring process for additional Sealzall units in the future. **Automated Full Lane Sealing** The Operator Controlled Crack Sealer will be demonstrated within the state of California in 2007 as a method of showcasing this technology and evaluating its near-term application potential. Based on Caltrans needs, a deployable machine concept of this technology would have to be developed and Caltrans customer support for the design secured. Ultimately a new development project would have to be created to build the deployable version of the OCCSM machine.	**Research Products** *Automated Longitudinal and Manual Full Lane Sealing* — A field deployable high production longitudinal and manual in-lane crack sealing system. *Automated Full Lane Sealing* — A deployable version of a random crack sealing machine. **Outcomes** • Perform crack sealing in the fastest and safest manner. The TTLS removed all workers from the roadway and allows for longitudinal cracks and joints to be sealed at about 4-5 times the rate as compared to typical manual operations. The Sealzall when deployed to Caltrans will further increase sealing production and reduce costs while extending machine functionally to sealing all pavement cracks with the addition of hand sealing capabilities with improved worker safety. Development of a deployable version of the OCCSM technology will provide the ultimate safety benefit by removing all workers from the roadway when sealing highway cracks while improving seal production and quality in addition. • Reduce traveler delays. The Sealzall machine will allow for a moving lane closure thus providing for increased traffic flow over manual operations. • Reduce operational costs. Labor savings alone for the Sealzall sealing longitudinal cracks is estimated to be up to $1.2 million per year and total cost savings at over $2 million per year. Sealzall and OCCSM demonstration results will provide for anticipated changes to business practices and/or machine developments necessary for full deployment.
Debris How can litter and debris be removed from the roadside in the safest and most efficient manner?	**Automated Roadway Debris Vacuum (ARDVAC)** ARDVAC was developed over several years and is a dexterous manipulator attached on a commercially available vacuum truck such as that used for cleaning storm drains. *Status* — The project led to a commercial machine available from VacAll. Caltrans will receive two machines by June 2007. AHMCT will participate in evaluating the efficacy of these machines. *Current Caltrans Deployment*: Stage 5. **Debris Removal Vehicle (DRV)** DRV prototype was developed and commercialized by vendor that could not provide a reliable commercialized machine. *Status* — The last machine delivered was repaired and upgraded by AHMCT and DOE to allow limited Field Pilot Stage testing. DOE is contracting with Heil to retrofit existing DRV prototype with a modified, commercially available robotic arm. Caltrans DOE has designed an end effector (clam shell). Pending successful field pilot stage, Heil will supply commercialized garbage trucks with arm. *Current Caltrans Deployment*: Stage 4.	**Enhanced Deployment Support for Debris Removal** Enhanced Deployment Support efforts should continue to track and document the use of the ARDVAC and DRV as it is used in actual Caltrans operations. These machines are expected to greatly reduce employee exposure to hazards and increase efficiencies. Weed removal tools should be integrated into ARDVAC operations and evaluated. Assessment of their usefulness to Caltrans operations is necessary and the efficacy of existing units like the Caltrans Barber litter picker must be evaluated and documented. The ARDVAC and DRV are high value machines that will probably be used by special crews. **Development of Low Cost Removal Equipment** Low cost debris removal equipment should be developed for individual maintenance yards and special applications. A current survey of Roadside Design and Maintenance practices as it applies to litter and debris removal is required. Equipment based solutions are required to increase efficiency.	**Research Products** *Enhanced Deployment Support for Debris Removal* — Enhanced support of diffusion of innovation process for Debris Removal products and processes. *Development of Low Cost Removal Equipment* — Development of low cost debris removal equipment. **Outcomes** • Perform Debris Removal in the fastest and safest manner — The ARDVAC removes all workers from the roadway and allows for faster operation than current manual ones. • Reduce traveler delays — Faster operation will result in reduced lane closure time. • Reduce operational costs — Cost effectiveness of machines in roadside applications is projected to be high. Based on increased speed of the operation, reduced labor and fewer injuries, each ARDVAC unit's cost savings can be up to $147,000 per year representing a 2.6 year payback on equipment cost. DRV is expected to provide similar cost savings. A 10 unit fleet of ARDVACs will potentially reduced annual Caltrans litter costs by $1.5 million while improving Level of Service. Litter and debris removal efforts are an annual cost of about $50 million a year to Caltrans. • Availability of low cost debris removal equipment will enhance safety and efficiency of small-scale, quick response debris removal operations.

Manual Tasks How can technology provide worker assistance for work zone manual tasks?	**Labor Intensive Manual Tasks** This study has been constrained to considering several scenarios which currently involve significant manual labor and more specifically has addressed the maintenance of vegetation on roadsides. The emphasis has been on identifying new innovative methods and comparing them to more conventional methods. Details of costs and benefits using IMMS data and other sources are being used to provide robust recommendations. *Current Caltrans Deployment*: Stage 1 **Human-Assist Non-Stationary Device for Lifting (HANDL)** This project began the development of an off-road device designed to handle payloads at or just beyond the threshold of safe human manipulation, such as crates, barrels, guard-rail sections, and sacks of building materials. The machine consists of an omnidirectional mobile platform and a grasp and lift manipulator. The omnidirectional platform allows the operator to drive the vehicle in any direction, instantly. This includes: moving laterally from rest, rotating in place, as well as simultaneous translation and rotation. The grasp and lift manipulator is designed to grasp a variety of objects without damage. To date the main component of the omnidirectional platform, the ball wheel based actuator system, has been built and proven in the laboratory. Additionally, the grasp and lift manipulator has been laboratory demonstrated. *Current Caltrans Deployment*: Stage 2	**Labor Intensive Manual Tasks — Ongoing** Find or develop new devices and/or new methods to make labor intensive roadside vegetation maintenance safer and more efficient. This is an area with very high potential for labor savings and injury reduction. **Human-Assist Non-Stationary Device for Lifting (HANDL)** The next phase of the project should involve building the complete omnidirectional platform, which involves designing and fabricating the multi-ball wheel based platform and the additional ball wheel actuation systems. This will allow additional laboratory testing of the system. An actual Caltrans task should be targeted and ancillary equipment developed to allow for completion of that task with the platform. Initially, work within the Equipment Service Center will allow fastest deployment from a laboratory demonstration system.	**Research Products** *Labor Intensive Manual Tasks: Ongoing* — Development of devices and/or new methods to make labor intensive roadside vegetation maintenance safer and more efficient. *Human-Assist Non-Stationary Device for Lifting* — An off-road capable device for assisting workers in the lifting and manipulation of a variety of typical Caltrans labor intensive tasks. **Outcomes** This is an area with very high potential for labor savings and injury reduction. *Labor Intensive Manual Tasks: Ongoing* — The Labor Intensive Manual Tasks project will compare approaches that are alternatives to current herbicide use. Reduction in herbicide use has increased manual labor requirements which increases injuries in this category. Annual operational cost directly associated with the vegetation control operations is over $30 million, thus labor savings have then potential to result in significant cost savings. *Human-Assist Non-Stationary Device for Lifting* — Perform Manual Tasks maintenance in the fastest and safest manner - The HANDL will reduce the number of workers on the road and will allow for faster task completion. Caltrans reports that over 16% of all injuries during the period 1994 through 1999 were incurred during lifting tasks and paid over $16 million during the 1990's for back strain injuries which are often caused by lifting tasks. By relieving a significant portion of required lifting, HANDL has the potential to lead towards significant cost savings.
Markers and Stripes How can innovative technologies and automation be utilized to enhance the safety and efficiency of RPM placement operations on the highway.	**Raised Pavement Marker (RPM) Placement** *Description* — Research existing, or develop original conceptual designs for innovative new methods and equipment to improve upon the conventional manual process of installing RPM's on the highway. *Status* — The project started with a thorough search of existing innovative RPM installation equipment and practices and presented this to the Caltrans project advisory group for review. A research plan was adopted to develop an original conceptual design to automate the installation operation for RPM's that meets Caltrans specific needs. A laboratory based demonstration system is under development to validate the conceptual design. *Outcomes* — Remove workers from direct traffic exposure, increase production speed, reduce RPM installation costs and improve installation quality. *Current Caltrans Deployment*: Stage 1	**Raised Pavement Marker (RPM) Placement — Development of Field Prototype** With the laboratory system validated, the next step will involve integrating the system on a trailer to permit limited field operational testing and Caltrans evaluation. Based on Caltrans evaluations, a proposal for a full scale deployable version of the automated RPM machine could be developed. Should the final version of the automated RPM machine be trailer based, equipment costs would plunge by eliminating the need for a dedicated Raised Pavement Marker truck. Ultimately detailed specifications would be developed allowing for commercial vendors to fabricate and sell a Raised Pavement Marker machine.	**Research Products** *Raised Pavement Marker Placement* — Field prototype of an advanced Raised Pavement Marker machine. **Outcomes** *Raised Pavement Marker Placement* — • Increase worker safety — The Raised Pavement Marker machine removes all workers from direct traffic exposure, as it allows markers to be placed without handling by a worker. • Increase speed of operation — Markers are placed at a continuous speed about 4-5 times faster rate than the current manual operation. • Reduce traveler delays — The higher rate of application of Raised Pavement Markers will reduce the amount of time of necessary lane closures. • Reduce operational costs — Create labor savings by reducing the number of workers based on the increase in speed of operation. • Improve quality — Automated placement leads to consistent quality of application.
Traffic Cones How can a lane closure be placed in the safest and most efficient manner?	**Automated Cone Machine** The Automated Cone Machine was developed and tested over several years and the technology lead to a commercialized machine. More recently, AHMCT staff have been tracking use of the TRAF-tech machine as it is being tested by several Caltrans Districts. A report will be developed discussing test results and the efficacy of the machine. *Current Caltrans Deployment*: Stage 5.	**Lane Closures: Diffusion of Innovation** Future efforts should continue to track and document the use of the equipment as it is used in actual Caltrans operations. To ensure availability, Caltrans must influence the design of the commercial machine(s) and traffic cones to reflect Caltrans operational requirements. Caltrans cone specification should be revised to require certain features to ensure reliable machine handling. These features already exist but are not reflected in specifications. Larger and heavier cones such as a 36 inch cone may be used in lane closures in the near future and machine placement will be necessary. Caltrans must provide incentives and remove disincentives for use of the machines by contractors. A simple cost benefit analysis does not reflect the benefits of safety and reduced exposure for the average Caltrans crew. A selection procedure should be developed to prioritize which Caltrans operations should be assigned the machine. Lane closure procedures and machines must be further developed to avoid any exiting of the vehicle to place signage. In high traffic volume areas, a heavier cone machine with attenuator and no shadow vehicle will be desired. A version of the Automated Cone Machine is currently available from TRAF-tech in two versions - one that carries 240 cones and one that is smaller, more versatile and carries 100 cones. TrafTech is rapidly developing changes and improvements to meet customer needs. The machine is in the early stages of development and guidance from Caltrans and other DOTs is necessary.	**Research Products** *Lane Closures: Diffusion of Innovation* — Enhanced support of diffusion of innovation process for Lane Closure products and processes. **Outcomes** *Lane Closures: Diffusion of Innovation* — • Perform Traffic Cone placement and retrieval in the fastest and safest manner. — The available cone machines eliminate the manual handling of the cones as they are placed and retrieved with a single in-cab operator. • Reduce operational costs — Direct cost savings are possible in regular high volume operations such as that on the Bay Bridge. During regular operations the added machine costs are comparable to the added costs of a shadow vehicle and the cost savings result from reduced exposure and associated injuries to workers as well as injuries incurred from manually handling cones.

Winter Maintenance

Research Area	*Recent and Ongoing Research*	*Future Research*	*Research Products and Outcomes*
Driver Assistance for Winter Maintenance How can advanced technologies be used to provide guidance to maintenance vehicle operators to enhance safety and efficiency, and to protect Caltrans assets such as guardrails?	**Magnet-Based Guidance for Snowplow and Rotary Plow Vehicles** A magnet-based guidance system was developed for snowplows. The system has been field-tested and deployed in District 2 (Burney) and District 3 (Kingvale). *Current Caltrans Deployment*: Stage 4. A magnet-based control system was developed for the rotary snow blower. The system was tested by PATH researchers at Kingvale. *Current Caltrans Deployment*: Stage 2. **GPS-Based Guidance for Winter Maintenance** A GPS-based mountain pass road opening guidance system has been developed. Testing of this system is on-going. System architectures for GPS-based guidance for snowplows and rotary plows are being revisited, and system development is on-going. *Current Caltrans Deployment*: Stage 2.	**GPS-Based Guidance for Winter Maintenance** Further testing and refinement of the road opening system based on operator feedback. Field testing and operator-based revisions and enhancements of GPS-based guidance systems for snowplow and rotary plow. **Plug-In Display-Based System for Driver Assistance for Maintenance Vehicles** Broad evaluation of Caltrans operations beyond winter maintenance to determine efficacy of similar guidance or tracking for other operations, e.g. paint striping, material tracking, etc. Evolve the GPS-based guidance system into a generic and portable in-cab display-based system for driver guidance for maintenance vehicles.	**Research Products** • Prototype guidance systems for road opening, snow plow and rotary plow operations. • Similar guidance systems for other Caltrans maintenance operations. **Outcomes** *GPS-Based Guidance for Maintenance —* • Safer road opening at the end of winter for closed passes. Also, anticipated time savings for this operation, estimated at 2 – 3 days with $800 - $1200 savings per pass opening. • Road opening system designed for portability, so it can be time-shared between passes, improving the benefit/cost. • More effective winter maintenance, particularly in severe storm events, with increased mobility for the public. Associated cost savings for Caltrans and the State. • Improved rotary plow operation will keep the blower from damaging guardrails, and greatly reduce the frequency of repair and replacement. At an average cost of approximately $100/meter of guardrail (Caltrans source), including material, equipment, and labor, the resulting savings will be large. Damaged guardrails are also a hazard to the traveling public, with associated liability risk to Caltrans. *Plug-In Display-Based System for Driver Assistance for Maintenance Vehicles —* • Additional benefits of GPS-based guidance and tracking across a broad spectrum of Caltrans operations outside of winter maintenance.
Obstacle Detection in Snow and Ice How can advanced technologies be used to protect Caltrans assets such as guardrails, rotary plows, and reduce problems associated with obstacle collisions?	**Obstacle Detection in Snow and Ice** Assess current methods and design of novel methods for guardrail protection. A side-fire radar-based system is being designed and developed to detect the presence of guardrails, and to provide range from the sensor to the guardrail. The system is in design and laboratory testing, and will be developed and demonstrated in the field. *Current Caltrans Deployment*: Stage 1.	**Obstacle Detection in Snow and Ice** Field Testing of the Side-Fire Radar System for Guardrail Detection and Ranging; Ruggedization and Deployment	**Research Products** • Prototype system for guardrail detection and ranging. **Outcomes** • Improved rotary plow operation will keep the blower from damaging guardrails, and greatly reduce the frequency of repair and replacement. At an average cost of approximately $100/meter of guardrail (Caltrans source), including material, equipment, and labor, the resulting savings will be large. Damaged guardrails are also a hazard to the traveling public, with associated liability risk to Caltrans.
Mobile Information Systems How can advanced technologies and communications systems be used to improve winter maintenance operations by providing enhanced situational awareness?	**Mobile Real-time Information System for Snow Fighters** This project developed an in-vehicle information system for snow crew supervisors that will lead to improved resource allocation, enhanced efficiency, and superior responsiveness of snow removal equipment and crews, thus lowering winter operational costs. *Status* —Prototype development is complete, and the system is available for Caltrans testing. *Current Caltrans Deployment*: Stage 2.	**Mobile Real-time Information System for Snow Fighters** • Controlled field-testing in a Caltrans winter maintenance corridor, with support by AHMCT. • Evaluation of the testing results and operator feedback, to consider any changes to the system or to the information content or format. Based on such evaluation, a follow-on research effort may be warranted, or the system could be transitioned towards deployment. • Quantitative analysis of the time and money savings provided by field presence of the supervisor, as well as detailed situational awareness in the field. • Integration with additional data sources such as WeatherShare.	**Research Products** • Prototype mobile information system for use by snow crew supervisors, in and near their vehicle; system will eliminate some trips by the snow crew supervisor back to the maintenance yard. **Outcomes** • Eliminating even one hour per day for trips back to the maintenance yard will yield estimated $7500 savings per snow season. • Keeping the supervisor in the field and providing enhanced situational awareness is expected to increase the overall effectiveness of winter maintenance operations, particularly during and around storms. • Improved resource allocation, enhanced efficiency, and superior responsiveness of snow removal equipment and crews, thus lowering winter operational costs. • Overall crew effectiveness will be enhanced by presence of the snow supervisor and enhanced situational awareness, providing all needed data to make informed decisions for the best treatments and responses for the storm event. • Efficiency and effectiveness will lead to reduced total costs for winter maintenance. Further testing and investigation is needed to quantify this. • Mobility benefits to the traveling public, at substantial cost savings in more urban areas such as Donner Summit. Additional benefits in terms of safety to the traveling public, with associated dollar benefits, as well as reduced liability for Caltrans.

Roadside

Research Area	*Recent and Ongoing Research*	*Future Research*	*Research Products and Outcomes*
Asset Management What are the best practices for assessing and managing roadside features? How can advanced technologies be used for monitoring and managing roadside features?	**Roadside Inventory Assessment Study** *Status* AHMCT has completed a comprehensive questionnaire and survey of stakeholders to determine best practices. This survey included other State Departments of Transportation, Counties, Cities, Companies, and other organizations. The results have been analyzed and best practices have been identified for a large set of roadside features. AHMCT is also looking at available technologies and is matching them to the best practices identified to make a set of recommended procedures for monitoring and assessment of conditions of roadside features. The kernel of a visualization tool based on Google Earth is also being developed to provide a visual tool for this task. The scope of the visualization tool is on handling culverts but can be enhanced to other roadside features. *Current Caltrans Deployment*: Stage 1.	**Development of Field Operational Guides for Each Caltrans Specific Roadside Asset** Based on the result of matching the available technologies with the best practices for each roadside assets and the recommended method develop field operational guidelines for all roadside assets important to Caltrans. **Expansion of the Visualization Kernel to a Comprehensive Roadside Asset management Tool** Expansion and full software development of the asset management tool, and evaluation by and deployment to Caltrans Roadside Maintenance. **Field Operation and Developing the Computerized Data Base of Caltrans Roadside Assets Using the Visualization Tool** Using the field operational guides to monitor conditions of and collect data on roadside assets and populate the data base in the Visualization Tool for enhanced decision support.	**Research Products** • Data on different inventory tracking practices. • Data on applicable technologies, tools and methods for inventory asset management. • Field operational guides for roadside inventory asset management • A visualization tool and a data base for culverts and beyond. **Outcomes** • Changing the business operation of Caltrans in roadside asset management by providing a uniform set of field operational tools and guidelines. • Changing the business operation of Caltrans in roadside asset management by providing a computerized method for decision support, monitoring and visualization. Computerized database costs related to asset management (for a small city) are on the order of $1.2 million per year. • Time savings through more effective planning of roadside maintenance operations. • Enable timely management of assets before they reach failure, with potential cost savings in the millions of dollars, related to culverts alone. • Additional cost savings related to liability reduction and litigation. This is a significant issue for Roadside Maintenance and Caltrans. Appropriate inventory asset management is a key element in liability risk management. Quantified values for this should be determined in conjunction with Roadside Maintenance. • Inventory asset management is essential in evaluating current and future Roadside Maintenance operating budgets. A fully populated and functional asset management tool would support such budget estimation as a primary function, and would lead to cost efficiencies in this regard.
Vegetation Control How can innovative technologies and automation be utilized to enhance the safety and efficiency of the control of roadside and landscaping vegetation and its associated operations?	**Vegetation Removal Tools** A recent project has designed a set of vegetation cutting tools that can be used in conjunction with the Automated Roadway Debris Vacuum (ARDVAC) machine in order to cut vegetation and to collect it with vacuum. The tools address various types of vegetation and include a tumbleweed collection device as well as two other devices for mowing and trimming. *Current Caltrans Deployment*: Stage 2 **Herbicide Vehicle** A machine known as the Intelligent Herbicide Application System (IHAS) has been in development for many years. A vision system is used to identify weeds to allow automated spot spraying while the truck is moving. Field testing has been limited and various technical problems exist on the latest prototype. Machine has potential to greatly reduce herbicide usage on the clear strip and shoulders where weeds are sporadically growing. *Current Caltrans Deployment*: Stage 4	**Vegetation Removal Tools** Development of tools to maintain roadside vegetation that includes a tumbleweed device as well as two other devices for mowing and trimming. **Herbicide Vehicle** A detailed review of the IHAS development is required with a cost benefit analysis. Capabilities must be compared to commercially available technology for weed recognition systems may be more viable and less costly. Caltrans experience with 'Weed Seeker' equipment must be collected and evaluated for efficacy. The goal is to find or develop a vehicle to selectively apply herbicide to unwanted plant growth.	**Research Products** *Vegetation Removal Tools* — A set of tools to be used in conjunction with ARDVAC to maintain roadside vegetation that includes a tumbleweed device as well as two other devices for mowing and trimming. *Herbicide Vehicle* — A vehicle to selectively apply herbicide. **Outcomes** • Perform roadside vegetation maintenance in the fastest and safest manner — The ARDVAC with vegetation tools will allow for removal of workers from the roadside for maintaining vegetation within close proximity to the roadway. The Herbicide vehicle will allow for greatly reduced use of herbicides in shoulder and clear strip maintenance. The results of the labor intensive tasks project will make recommendations for new equipment and/or methods to more efficiently maintain roadside vegetation. • Reduce environmental impacts — The Herbicide vehicle has the potential to reduce the use of herbicide significantly by applying it to only unwanted vegetation as opposed to broadcasting it over a large area. • Reduce labor costs — Reduction in herbicide use has increased manual labor requirements which increases injuries in this category. (See also "Labor Intensive Manual Tasks") Annual operational cost directly associated with the vegetation control operations is over $30 million, thus labor savings have the potential to result in significant cost savings.

Homeland Security

Research Area	*Recent and Ongoing Research*	*Future Research*	*Research Products and Outcomes*
Rapid Road Repair How can roadways be open for emergency vehicles as quickly as possible following catastrophic events?	**Rapid Road Repair** Research into Rapid Road Repair Strategies. *Status* This project researched rapid road repair best practices, analyzed damage scenarios, developed analytical methodologies, and recommended development of a Rapid Road Repair machine. Current best practices were found to be laborious, costly, and slow. The assessment of damage scenarios provides a basis for understanding earthquake road damage and what damage types can be quickly repaired. After reviewing several ideas for a temporary repair system, this project presents a design concept for a repair structure that can be towed as a trailer to the site of earthquake road damage and deployed as a small bridge over the impassable section of road. *Current Caltrans Deployment*: Stage 1	**Rapid Road Repair** Future work should focus on the continued development of the tools and procedures Caltrans needs to maintain a right-of-way during emergency situations. Tool development will include the detailed design, fabrication and controlled feasibility testing of a system consisting of a trailer support structure and a Wheel Track driving surface, along with the additional supports and ramps, to address all the repair types, from simple cracks to complex vertical offsets with canted road surfaces. Procedure development will be Caltrans specific and will be tailored to local requirements.	**Research Products** *Rapid Road Repair* — A rapid road repair machine to deploy supports and ramps over fissures and other road damage to allow for emergency vehicles to respond in catastrophic events. **Outcomes** *Rapid Road Repair* — Improved ability to respond to road damage. Such a rapid road repair machine will allow for significantly faster road opening for emergency vehicles after catastrophic events and could have a profound impact in terms of saved lives and structures.

Planning and Operations

Research Area	*Recent and Ongoing Research*	*Future Research*	*Research Products and Outcomes*
Best Practices How can AHMCT help gather and present information related to best practices in other agencies and industries?	**Vehicle Allocation Methodology** *Description* Best practice issues addressed were: How can fleet be right-sized? How can time-to-acquire vehicles be reduced? What is the best way to gather fleet utilization data? Co-Sponsor: Dept of General Services. Stakeholders: all State Agencies. *Status* Study completed. Deployed: Process/negotiated deal to reduce vehicle acquisition time from 2 to 0 years. Process/negotiated deal to acquire vehicle utilization data for ~150 $/vehicle/hardware. Concepts and process documented, publicly presented, and web accessible. First to implement will probably be Dept of Corrections and Rehabilitation. *Current Caltrans Deployment* — Stage 2: Laboratory Prototype Stage	**Vehicle Allocation Methodology Pilot Project** Implement VAM recommendations for Caltrans Division of Equipment pilot project: Focus vehicle purchase and usage reviews on fleets rather than on vehicles. Associate vehicles with tasks. Create tables of allocation. Identify best practices using timely usage data.	**Research Products** *Vehicle Allocation Methodology* — Changes in Vehicle Allocation policies and procedures. **Outcomes** *Vehicle Allocation Methodology* — Stage 4: First Application Field Pilot Stage For Caltrans Division of Equipment: • Reduce vehicle acquisition time from 2 to 0 years. • Acquire vehicle utilization data for ~150 $/vehicle/hardware. • Encourage fleet downsizing (2-5%). • Encourage technology innovation.
Business Cases Can AHMCT developments be justified by economic analysis?	**Business Cases** *Description* — Development of business cases for the deployment of AHMCT projects. *Status* While the potential cost savings from AHMCT technology is enormous, these savings have rarely been formally documented nor have business models/cases been typically developed. As such, the economic impact of AHMCT technology has not been established nor used to promote the adoption and use of the technology either internally to Caltrans or externally to the state and the nation. This project has thus developed a business analysis that examines the costs and benefits of proposed solutions at multiple levels: a cost/benefit analysis for individual Caltrans tasks; a return on investment analysis for the purchase or lease of appropriate machinery within Caltrans divisions; and a cost/benefit analysis that factors in public welfare and policy objectives (i.e., reduced traffic delays, injury accidents). A business case has been developed for a different project each quarter.	**Business Cases Strategies** Future work will continue to develop business cases thus providing the justification for project deployment. The future work will analyze projects that are earlier in the deployment process. This should allow for the development of methodologies for evaluating project potential much earlier and thus has the potential to concentrate efforts on the most promising projects from an economic viewpoint.	**Research Products** *Business Cases Strategies* — Business Cases for various AHMCT projects. **Outcomes** *Business Cases Strategies* — • Reduce operational costs — Cost effectiveness of operations will be improved by developing machines and processes that show the greatest cost/benefits.
Deployment Support How can AHMCT help support deployment of innovative highway technology?	**Deployment Support** Cone Machine, Bridge Height Measurement System, Transfer Tank Longitudinal Sealing System	**Deployment Support** Future work in deployment support includes working with Caltrans field operational personnel for field testing of the various equipment developed at AHMCT including participating in field tests, documenting test results and providing general support including maintenance and troubleshooting, serving as a liaison to AHMCT technical staff thus expediting the development and commercialization process, providing training of Caltrans operators, and developing test standards and specifications for other commercially available devices useful in Caltrans operations.	**Research Products** *Deployment Support* — Support of diffusion of innovation process for selected products. **Outcomes** *Deployment Support* — Faster deployment of beneficial tools, methods, and vehicles.
Driver Behavior How can Caltrans minimize the user burden during household travel surveys, and provide accurate, reliable, and spatially dense traveler behavior information at a significantly reduced cost?	**GPS-Automated Travel Diary (GPS-ATD), or PDA Type Travel Behavior Data Monitor** *Description* Development of a digital electronics-based data monitor with GPS integration for travel diary. Improved traveler behavior information is vital to travel demand modeling, transportation management, and land use planning. AHMCT has developed a prototype GPS-Automated Travel Diary (GPS-ATD) to replace traditional paper-and-pencil and computer-assisted approaches for travel surveys. The GPS-ATD minimizes the user burden during longitudinal travel behavior surveys, while providing accurate, reliable, and spatially dense traveler behavior data at a significantly reduced cost. *Status* Prototype GPS-ATD units have been delivered to Caltrans Transportation System Information (TSI), who are now testing and evaluating the units, with ongoing support by AHMCT. *Current Caltrans Deployment*: Stage 2.	**GPS-Automated Travel Diary** Hardware design revisions in support of mass production. A large number of units will be needed to support the Caltrans 2010 Longitudinal Travel Behavior Survey. A survey using GPS-ATD will produce large and complex sets of spatiotemporal data, and thus, Caltrans TSI Division will need new GPS-ATD data analysis tools with features such as: automated data extraction and downloading tool; travel behavior data analysis and reporting tool for regional, interregional, and statewide queries; and customized Geographic Information System (GIS) tool with spatial interpretation and travel survey outputs in the form of tables and maps. Analysis of this data will require development of appropriate techniques and tools to support and facilitate extraction and reporting of useful survey data—future work would research and develop such techniques and tools to enable planners to effectively search and query the large set of data to generate general statistics. At the end of the work, the tools, prototypes, and documentation would be ready for transition to deployment and/or commercialization, and for use in the envisioned Caltrans 2010 Longitudinal Travel Behavior Survey.	**Research Products** • GPS-ATD personal and vehicular prototype units. • Tools for data analysis and automation. **Outcomes** • Significant change to travel survey implementation and subsequent data analysis. • Potential change in frequency and ease of travel surveys, with improvements for demand modeling, transportation management, and land use planning, amplifying the benefits of these areas to Caltrans and to the traveling public. • Minimize user burden during household travel surveys, while providing accurate, reliable, and spatially dense traveler behavior information at a significantly reduced cost. In particular, the GPS-ATD will reduce or eliminate under-reported trips. • Additionally, the GPS-ATD will: provide activity-time-space relationships, capture all modes of transportation and mode connectivity changes, provide strong support for automated data analysis, and allow survey duration up to 30 days. • Greatly reduced cost for implementation of travel surveys, as well as for the subsequent analysis and reporting. The 2001 Statewide Travel Survey cost was approximately $2 million. Much of this is related to implementation, analysis, and reporting. With the GPS-ATD, a significant part of this cost can be eliminated.

Sensing and Modeling How can advanced remote sensing and modeling be used to improve management of Caltrans assets, including structures and roadways. How can these technologies and methods improve safety, productivity, and efficiency?	**Bridge Profile Measurement System** Laser-based system for vertical and horizontal dimensions, senses bridge profile data from a vehicle moving at highway speed. Profile dimensions are extracted using custom interactive software, with output as a standard Caltrans profile diagram. Proof-of-concept prototype was completed and tested in early 2005. 2nd generation hardware and software are being developed. Two completed systems will be field-tested by Structures Maintenance in early 2007. *Current Caltrans Deployment*: Stage 3-4. **Standards and Specifications for 3D Laser Scanning in Caltrans Projects** Test and develop benchmarking standards for evaluation and selection of 3D scanners in Caltrans applications. The literature, product and standards review is complete. Controlled tests and pilot studies concluded. We have tested scanners by several hardware vendors. Software evaluation is in progress. Standard and workflow recommendation will be completed in 2007. *Current Caltrans Deployment*: Stage 1.	**Bridge Profile Measurement System — Intensive Field Testing** Intensive field trial testing is needed, including support by AHMCT for Structures Maintenance testing, and software revisions based on their feedback. In addition, the structure diagram generation software will be developed. **3D Laser Scanning in Caltrans Projects — Field Trials** Field trials and demonstrations of the recommended laser scanning workflow. Foster adoption and use by Caltrans in diverse applications. **Vehicle-based System for 3D Laser Scanning in Caltrans Projects** Develop a new vehicle platform for 3D laser scanner similar to the Caltrans Vanguard System for Total Station.	**Research Products** *Bridge Profile Measurement System* — Northern and Southern California region Structures Maintenance will each have a complete system for their use. *3D Laser Scanning in Caltrans Projects* —Standards and specifications for use of 3D laser scanning in Caltrans projects, by Caltrans and its contractors. Standards and specifications will support selection and procurement of laser scanners, along with subsequent use. Field trials will foster Caltrans adoption and use of this technology, and development of a vehicle-based system (Vanguard-like) will greatly improve the safety of survey crews. **Outcomes** *Bridge Profile Measurement System: Intensive Field Testing —* • Collecting and updating vertical and horizontal clearance profiles will be faster, safer, and easier. Data collected from a vehicle traveling at highway speeds. Clearance profiles used to support oversize permit generation. • Eliminate lane closures used in current operations, estimated savings of $5000 per closure eliminated. • Remove Structures Maintenance personnel from the roadway with high-speed traffic and put into vehicle, increased safety. • Improved data integrity and accuracy means reduced opportunity for human error going from measurement, recording, transcription, and database update. • Reduction in likelihood of bridge strikes due to data errors, with implications for liability. *Standards and Specifications for 3D Laser Scanning in Caltrans Projects —* • Approximately 30% overall time savings over conventional methods, and 20 – 50% field time reduction. • Approximately $1200 savings per mile surveyed—includes 30-75% field crew size reduction. • Eliminate lane closures, and reduce survey crew traffic exposure, with associated cost savings.
Open-Source Software for Maintenance & Operations How can AHMCT facilitate Caltrans' use of Open Source Software in Advanced Traffic Management Systems to dramatically reduce lifecycle costs of ATMS ownership? How can Open-Source Software be leveraged to reduce costs and improve efficiency across Caltrans operations?	**Open Advanced Traffic Management System** Developing Advanced Traffic Management System (ATMS) components based on open standards, open software, and commodity computer hardware. *Status* Literature, products, and standards review is complete, and documented in an interim report. Review of current Caltrans operations is in progress. Project is now at a checkpoint wherein we, in conjunction with Caltrans management, are evaluating the future direction of the project, including evaluation of existing open-source ATMS for adaptation and enhancement for Caltrans use. *Current Caltrans Deployment*: Stage 1.	**Open Advanced Traffic Management System** Within the existing project, complete update on scope to leverage open source in Caltrans ATMS operations, develop a proof-of-concept, develop an ATMS testbed, validate the system in the testbed, and perform initial testing in a Caltrans setting. Evaluate the testing results and update the system, then move the system to field demonstration and field pilot stages. Develop and maintain an Open Source Consortium Community to facilitate future Open-Source ATMS development. Expand towards Open-Source Software for Transportation Maintenance, Construction, and Operations. **Open Source for Maintenance & Operations** Initiate and maintain an Open-Source Web-Based Community for Highway Maintenance and Operations. Leverage the work done in this area within the ATMS project, and develop a National or international community for development and support of Open-Source Transportation Planning, Maintenance, Construction, and Operations.	**Research Products** *Open Advanced Traffic Management System —* • Open-Source components or complete system for Advanced Traffic Management. • Unified ATMS for all of Caltrans. • National (or international) community for development and support of Open-Source Software for Transportation Planning, Maintenance, Construction, and Operations. **Outcomes** *Open Advanced Traffic Management System —* Open-Source Advanced Traffic Management System will dramatically reduce lifecycle costs of ATMS ownership. Caltrans estimates that several million dollars per year can be saved by moving from a single-source ATMS to multi-sourced hardware and open-source software. • Elimination or reduction of up-front and on-going support costs, currently about $3 million each year to maintain existing ATMS in five districts. Estimates are that using the existing approach, standardizing ATMS throughout all twelve districts will cost about $7 million per year. Caltrans also notes several million dollars in one-time software licensing and hardware costs. • Eliminate vendor lock-in., with benefits to the State in terms of flexibility, cost, and negotiating power. • Availability of a base ATMS that is used Statewide or Nationwide will facilitate an open and competitive ecosystem for commercial entities as well, with advantages to the DOT and business. • National (or international) community for development and support of Open-Source Transportation Planning, Maintenance, Construction, and Operations. • Application of similar approaches, technologies, and communities throughout Caltrans Transportation Maintenance, Construction, and Operations will provide major (multiple tens-of-millions of dollars) savings, and greater flexibility and performance.